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Dynamic Analysis of Steel Frame Using Manufactured Viscous Damper

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Abstract : A five storey single bay steel moment resisting frame with manufactured viscous damper is analyzed for Bhuj earthquake acceleration data of January 26,2001 using SAP 2000v14.0 analysis tool. Six different steel frame model is set up in which placement of damper is varied. Time history analysis was carried out and the output parameters like displacement, velocity, acceleration and base shear were tabulated and graphical results were also obtained. The results showed that the steel frame performed better when manufactured viscous damper is placed on all the floors as there is larger reduction in the drift, velocity, acceleration, but larger increase in base shear .

Key words : Time History analysis, Manufactured Viscous Damper, Steel Frame, Bhuj earthquake data.

I. INTRODUCTION

The number of tall buildings constructed today are increasing. Mostly, these structures are of low natural damping. So, increasing damping capacity of structural system or considering the need for other mechanical means to increase the damping capacity of the building has become increasingly common in the new generation of skyscrapers. The control of vibration produced by earthquake can be done by various means such as modifying rigidities, masses, damping or shape or by providing passive or active counter forces. In the present study use of manufactured viscous damper in reducing the vibration is studied.

A *MODEL DESCRIPTION*

In the present paper, the study is done using the manufactured viscous damper. The five storey single bay steel frame is modelled using sap 200 V14..0 . The loads are taken as according to IS 800:2007 for office use. The beams are designed as ISMB 500 and columns are designed as ISWB 600. The base of the frame is assigned fixed. The bhuj earthquake acceleration data for first fifty seconds is used for the analysis. The model of the steel frame without damper as well as with damper is shown in figures 1 and 2 respectively.

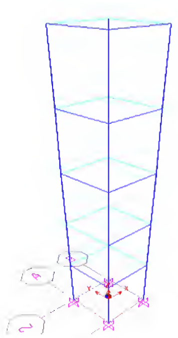

Fig 1 : model of steel frame without damper

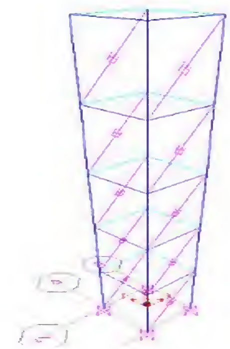

Fig 2 : model of steel frame with damper on all floors

Each bay is 3m in length and the storey height is 4m.. Loads are considered according to Indian standards.

TABLE 1 : DATA USED FOR ANALYSIS

Storey height	4m
Number of bays in x direction	1
Number of bays in y-direction	1
Live load	2.5 KN/m^2
Roof load	2.5KN/m^2
Slab thickness	120mm

II. MODELLING OF DAMPER AND ANALYSIS

The selection of design of design of dampers is similar to that of the selection and design of beams and columns in the building. The first step is selecting the location for manufactured dampers. Several positions pose no problem to owner since they are hidden from public view. Several other position requires the give and take with owner . Therefore, the design differs in both regards.The next step is to determine the size of the dampers i.e. the value of "C", to be used for the analysis. It is similar to determining the size of the column in the steel building. The basic equation of motion of structure is equal to

$$M\ddot{x}(t)+(C_{nd}+C_{md})\dot{x}(t)+Kx(t)=M[I]a(t)$$

The total damping is equal to

$$C=C_{nd}+C_{md}$$

Using fundamental natural frequency and mode shape of vibration

$$2\xi\varpi=\{[\phi_1]^TC[\phi_1]\}/\{[\phi_1]^TM[\phi_1]\}=\{[\phi_1]^TC_{nd}[\phi_1]\}/\{[\phi_1]^TM[\phi_1]\}$$
$$+\{[\phi_1]^TC_{md}[\phi_1]\}/\{[\phi_1]^TM[\phi_1]\}$$

The first term on right hand side of equation, uses

proportional damping matrix, hence no coupling between any two modes,
Therefore,

$$C_{md} = \{[\phi_1]^T C_{md}[\phi_j]\}/\{[\phi_1]^T M[\phi_j]\}=2\xi_{md}\omega_1..(a)$$

In the present analysis,
Load due to self weight = 3KN/m^2
Load due to floor finish= 0.09KN/m^2
Load due to roof finishing=1KN/m^2
Total dead load=4.09 KN/m^2
Load due to beam ISMB 500 =10.428KN
Load due to column ISWB 600 =23.216KN
Total Floor load = 36.81KN
Live load on floors=92.954KN

$$[M]\ NSec^2/mm = \begin{bmatrix} 9.475 & 0 & 0 & 0 & 0 \\ 0 & 9.475 & 0 & 0 & 0 \\ 0 & 0 & 9.475 & 0 & 0 \\ 0 & 0 & 0 & 9.475 & 0 \\ 0 & 0 & 0 & 0 & 9.475 \end{bmatrix}$$

The stiffness of the structure is obtained as,

$$[K]\ N/mm = \begin{bmatrix} 1589.49 & -794.745 & 0 & 0 & 0 \\ -794.745 & 1589.49 & -794.745 & 0 & 0 \\ 0 & -794.745 & 1589.49 & -794.745 & 0 \\ 0 & 0 & -794.745 & 1589.49 & -794.745 \\ 0 & 0 & 0 & -794.745 & 794.745 \end{bmatrix}$$

From equation (a), finally the value of C_{md} that is the manufactured viscous damper is obtained as,

$$C_{md} = 728.128\ N.Sec/mm.$$

The value is now entered in the SAP 2000 V14.0 analysis tool as two joint link. Firstly, the Time history analysis is done without addition of damper to the steel frame. Then the analysis is performed on the structure by adding the damper to the structure. The bhuj earthquake data used for the analysis is as shown in figure 3..

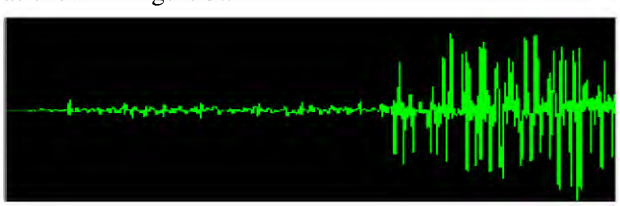

Fig 3 : input bhuj earthquake data

The damper is placed at ground floor, first floor, second floor, third floor, fourth floor, fifth floor respectively and the analysis is performed. Then lastly the damper in placed on all the floors and the analysis is done. The graphical results of the displacement, velocity, acceleration and base shear are captured from the analysis tool and the results are tabulated. The results showed that the maximum reduction in displacement, velocity and acceleration was seen when the dampers was placed on all the floors. The increase in base shear was observed when the dampers were placed on all the floors.

III. RESULTS AND TABLES

a) The displacement, velocity and acceleration when no damper is placed in steel frame.

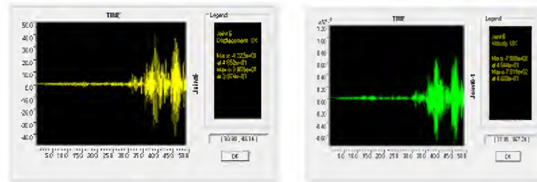

Fig 4&5 : displacement and velocity

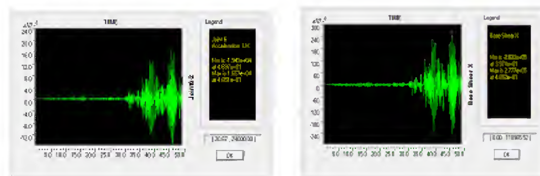

Fig 6&7 : acceleration and base shear.

b) The displacement, velocity and acceleration when the damper is placed on all stories of the frame:

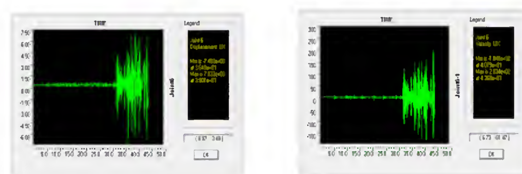

Fig 8&9: displacement and velocity

Fig 10 & 11 : acceleration and base shear.

c) TABULATION OF RESULTS

TABLE 2 : RESULTS OBTAINED

	Displacement (mm)	Velocity(mm/sec)	Acceleration (mm/sec^2)	Base shear (KN)
Bare frame	39.55	800	16570	123
1st floor damped	36.72	701.1	16440	194.7
2nd floor damped	35.16	684	16320	270.9
3rd floor damped	34.36	749.2	15260	255.5
4thfloordamped	32.92	596.5	12930	275.3
5thfloordamped	29.62	455.3	8424	277.7
All floors damped	7.033	203.4	6514	310.3

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As per the IS 1893(PART 1):2002, the maximum drift the structure can undergo is 0.004 times the total height of the structure. The drift obtained in the present analysis is within this permissible limit. There is reduction in the responses like displacement, velocity and acceleration when the damper is placed in the frame. Hence, the use of viscous dampers reduced the responses. The main purpose of the study was to observe reduction in displacement, velocity and acceleration when subjected to time varying loads like earthquake loads. Hence, viscous dampers are effective in reducing the responses. However, other kinds of dampers were not studied.

IV. CONCLUSION

Current trends in construction industry demands taller and lighter structures, which are also more flexible and having quite low damping value. This increases failure possibilities and also, problems from serviceability point of view. Several techniques are available today to minimize the vibration of the structure, out of which concept of using of viscous dampers is one.The present study is made to study the effectiveness of using the viscous dampers in control of vibration of the structure. A preliminary design method of arriving at the value of the damping coefficient 'C' was adopted. A moment resisting five storey steel structure was modeled using SAP analysis tool.The structure was analyzed once without a damper and then with the damper for bhuj earthquake using time history analysis.

1. The responses such as displacement, velocity and acceleration are minimized when the viscous dampers are added to the fifth storey of the structure.
2. When the damper is placed at the top storey, the drift is less. Hence, it can be concluded that the placement of the damper plays an important role in the vibration control of the structure.
3. The base shear of the structure increases with the damper placed in the structure than when it is not placed.
4. When the damper is placed on all the floors, there is much larger reduction in the drift, velocity and acceleration. But it obstructs the placement of doors and movement of people.
5. Also because of the cost of production of the viscous damper is more, most of the times it is not recommended to place viscous dampers on all stories.
6. Hence, from the present analysis, the placement of damper on the top storey is recommended.

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